NOTE *Parasitology*

Developmental morphology of *Knemidokoptes pilae* on an infested red-crowned parakeet (*Cyanoramphus novaezelandiae*)

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ABSTRACT. A captive 4-year-old female red-crowned parakeet (*Cyanoramphus novaezelandiae*) presented with anorexia, diminished activity and thick, beige, crusted lesions over the cere, legs, wings and cloaca. Deep skin scrapings from various lesions identified *Knemidokoptes pilae* as the causative agent. For treatment, the crusts were debrided, and the lesions were topically treated with ivermectin, chlorhexidine and silver sulfadiazine. The parakeet died the day after treatment. Previous studies examining *K. pilae* have focused primarily on the morphologic characteristics of adult female mites. This study presents a more comprehensive morphologic analysis, with examination of *K. pilae* at different stages of development (eggs, larvae and adult males and females).

KEY WORDS: *Cyanoramphus novaezelandiae, Knemidokoptes pilae*, knemidokoptic mange, morphology, parakeet

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Knemidokoptic mange is a parasitic disease caused by *Knemidokoptes* spp. (family: Knemidokoptidae) and is characterized by dermatologic lesions, encrustation, anorexia and sometimes death in birds [9, 11]. *Knemidokoptes* spp. are burrowing mites that invade the feather follicles and skin of wild and domestic birds, spending most of their time under the skin [6, 12]. On the basis of recent phylogenetic analyses, some researchers have suggested that the family Knemidokoptidae should be reduced to a subfamily and included within the family Epidermoptidae [10, 12].

The red-crowned parakeet (*Cyanoramphus novaezelandiae*), also known as the red-fronted parakeet, originated as a species in New Zealand and then dispersed across the ocean [2]. Recently, numbers of red-crowned parakeets have declined due to habitat loss, introduction of predators and psittacine beak and feather disease; indeed, the species is considered "near threatened" by the International Union for Conservation of Nature and Natural Resources [1].

Three red-crowned parakeets (two males and one female) were reared in O-World Zoo (36°17′19.00″ N, 127°23′52.04″ E) in Daejeon, Korea. The red-crowned parakeets were caged with birds of other species and fed a diet of parrot food and vegetables, including lettuce and cabbage, twice a day. The 4-year-old female red-crowned parakeet presented with anorexia, diminished activity and thick, beige, crusted lesions on the cere (Fig. 1A–1C). Physical examination following capture revealed similar skin lesions over the legs, wings and cloaca (Fig. 1D–1F).

To diagnose the causative agent, deep skin scrapings were taken from various body lesions and treated with 10% potassium hydroxide solution to induce separation of the mites from the host tissue. Numerous mites were observed by microscopy (Fig. 2A). The specific species was identified based on the morphology of the mites, clinical signs and host specificity. Broken dorsal striations forming a scale-like pattern are characteristic of both *K. pilae* and *K. mutans* [14]; because of these similar morphological characteristics, it is difficult to differentiate *K. pilae* from *K. mutans* by morphology alone [11]. One study indicated that the anal slit of *K. pilae* is seen from the dorsal view, while that of *K. mutans* is not [11]. In addition, the presence of lesions on the cere and beak is distinct characteristics of *K. pilae* infestation [11, 12]. The host specificity of parakeet also led us to identify the causative agent as *K. pilae* [6, 11].

To treat the knemidokoptic mange, crusted lesions were debrided with sterile forceps. Ivermectin (Ivomec 1% injection, Merial, Lyon, France) diluted 1:10 with propylene glycol, chlorhexidine (Hexamedine, Bukwang Pharmaceutical, Seoul, Korea) and silver sulfadiazine (Silmazine 1% cream, Dong Hwa Pharmaceutical, Seoul, Korea) were topically applied to the lesions. The red-crowned parakeet was kept in quarantine after treatment, but was found dead the following day.

Until now, description of the morphological characteristics of Knemidokoptidae has been primarily limited to adult females, with virtually no description of male or larval morphology, especially in the case of *K. pilae* [6, 11, 14]. In this study, various developmental stages (eggs, larvae and adult males and females) of *K. pilae* were detected on the skin lesions (Fig. 2). Adult females were short and round, had eight legs and measured approximately 600 μm long by 500 μm wide (Fig. 2B and 2C). The legs of females, which were shorter than those of males, were segmented

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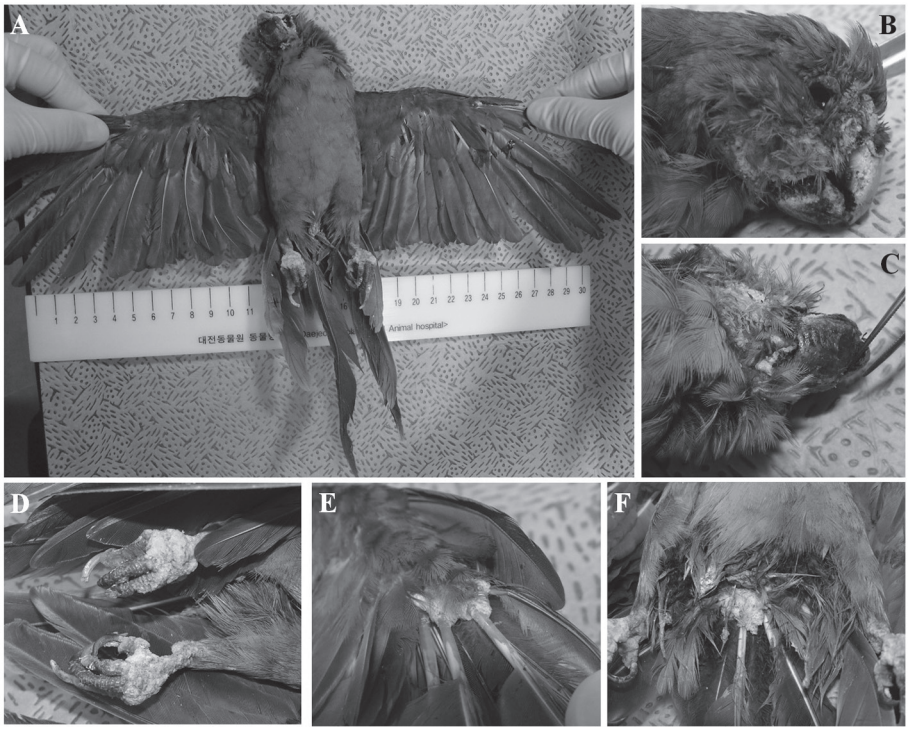

Fig. 1. Gross appearance of knemidokoptic mange on a captive 4-year-old female red-crowned parakeet (*Cyanoramphus novaezelandiae*). (A) Ventral view of infested parakeet. (B–E) Close-up views of crusted lesions observed over the cere (B, C), legs (D), wings (E) and cloaca (F).

and lacked suckers. As described in a previous study [14], the dorsal striations of *K. pilae* females were broken and formed a scale-like pattern (Fig. 2B, asterisk); however, triangular setae, which are characteristic of sarcoptids, were not observed. The ventral striations of *K. pilae* females were simple and unbroken (Fig. 2C, asterisk). On the dorsal surface, there was a pronotal shield with one transverse and two longitudinal chitinized bars (Fig. 2B). Additional prominent characteristics of adult female *K. pilae* included an anal slit positioned on the dorsal aspect (Fig. 2B, black arrowhead) and two short setae at the terminus of the idiosoma (Fig. 2B, white arrowheads).

Adult males were oval in shape, approximately 350 μm long by 250 μm wide (Fig. 2D). The males had eight segmented legs that were longer than those of females and featured long, unjointed pedicels with suckers (Fig. 2D, white arrows and inset). Two long setae were observed at the idiosoma terminus in males, in contrast to the shorter setae observed in females (Fig. 2D, arrowhead).

Larvae had morphology similar to that of adult males, but with only six legs (Fig. 2E and 2F). The larvae were smaller than male and female adults, at approximately 300 μm long by 200 μm wide. Larvae had long, unjointed pedicels with suckers at the end of each leg, similar to those of adult males (Fig. 2E, inset and Fig. 2F, white arrows). There were three setae at the end of each leg (Fig. 2F, inset); those on the first and second pairs of legs were short and similar in length, but one seta on the third pair of legs was distinctly longer than the other two (Fig. 2F, black arrows). Larvae had two long setae at the idiosoma terminus, similar to those of adult males (Fig. 2D and 2E, arrowheads).

The reproductive biology of *Knemidokoptes* spp. has yet to be clearly elucidated. For example, *K. gallinae* is ovoviviparous [15], *K. jamaicensis* is viviparous [4], and adult females of other Knemidokoptidae species are larviparous [7]. In this study, multiple embryonated eggs (300 μm long by 200 μm wide) were observed (Fig. 2G), suggesting that *K. pilae* is likely to be ovoviviparous; however, the possibility of oviparity cannot be excluded. Thus, the reproductive biology of Knemidokoptidae clearly requires further investigation.

Knemidokoptic mange can be quite detrimental to birds, and clinical infestation by *Knemidokoptes* spp. is associated with conditions of stress and malnutrition [8]. We suspect that a stressful caged environment hastened the death of the red-crowned parakeet infested with *K. pilae*. Knemidokoptic mange is transmitted by direct contact between birds, and interspecies transmission is thought to be rare [5]. The cagemates of the affected bird in the present study were examined for knemidokoptic mange, but showed no clinical manifestations of infestation. This suggests that the immunologic status of an individual bird could be an important predisposing factor for infestation by mites [8]. Since small birds are vulnerable to stress, early diagnosis is critical for the prevention of parasite transmission and development of disease [3]. Lesions caused by an avian poxvirus may resem-

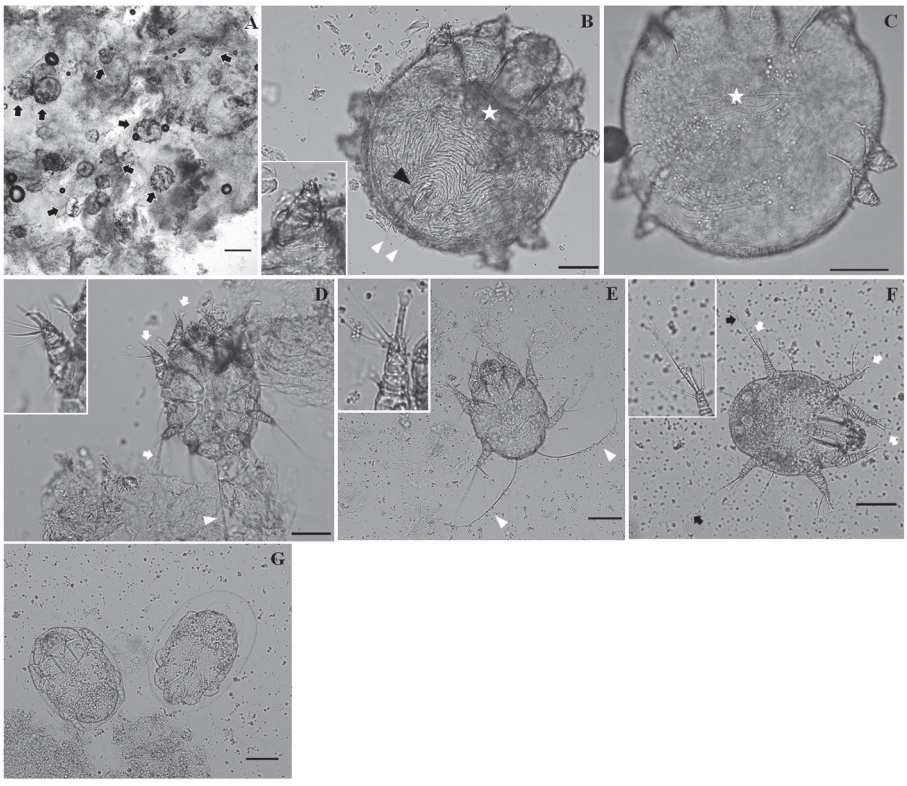

Fig. 2. Microscopic examination of *Knemidokoptes pilae* isolated from a red-crowned parakeet (*Cyanoramphus novaezelandiae*). (A) Numerous *K. pilae* (black arrows) are observed in a deep skin scrape of a lesion. (B) Dorsal view of an adult female, showing broken dorsal striations forming a scale-like pattern (asterisk) and an anal slit (black arrowhead). The legs are segmented, shorter than those of males and lack suckers (inset to B). Two short setae are present at the idiosoma terminus (white arrowheads). (C) Ventral view of an adult female, showing simple, unbroken striation (asterisk). (D) An adult male with legs having long, unjointed pedicels and suckers at the ends (inset to D, white arrows). Two long setae are observed at the idiosoma terminus (white arrowhead). (E, F) Larvae with legs having long, unjointed pedicels and suckers at the ends (inset to E, white arrows). Three setae are present on each leg, but one seta on the third pair of legs is distinctly longer than those on the first and second pairs of legs (inset to E, black arrows). Two long setae at the idiosoma terminus are observed (white arrowheads). (G) Embryonated eggs of *K. pilae*. Bars represent 500 μm in A and 100 μm in B through G.

ble those caused by *Knemidokoptes* spp.; therefore, poxvirus infection should be included in the differential diagnosis [5].

In the present study, we report the diagnosis and clinical course of a captive red-crowned parakeet infested with *K. pilae* and describe the morphological characteristics of *K. pilae* at various developmental stages. While previous studies have primarily focused on the morphology of adult female *K. pilae* [6, 11, 13, 14], our study provides valuable insight into the developmental morphology and reproductive biology of *K. pilae*.

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